



Airborne Hyperspectral Survey of Afghanistan 2007: Flight Line Planning and HyMap Data Collection

By Raymond F. Kokaly, Trude V.V. King, and K. Eric Livo

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
square kilometer (km ²)	0.3861	square mile (mi ²)
kilometer per hour (km/h)	0.5400	knots (kts)
kilometer per hour (km/h)	0.6214	mile per hour (mi/h)

Vertical coordinate information is referenced to the “North American Vertical Datum of 1988 (NAVD 88)”. Horizontal coordinate information is referenced to the “WGS Datum of 1984 (WGS 84)”. Altitude, as used in this report, refers to distance above the vertical datum.

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Introduction

Hyperspectral remote sensing data were acquired over Afghanistan with the HyMap imaging spectrometer (Cocks and others, 1998) operating on the WB-57 high altitude NASA research aircraft (<http://jsc-aircraft-ops.jsc.nasa.gov/wb57/index.html>). These data were acquired during the interval of August 22, 2007 to October 2, 2007, as part of the United States Geological Survey (USGS) project "Oil and Gas Resources Assessment of the Katawaz and Helmand Basins". A total of 218 flight lines of hyperspectral remote sensing data were collected over the country. This report describes the planning of the airborne survey and the flight lines that were flown. Included with this report are digital files of the nadir tracks of the flight lines, including a map of the labeled flight lines and corresponding vector shape files for geographic information systems (GIS).

Background

The USGS received funds in 2005 from the government of Afghanistan to support the acquisition of new airborne geophysical (gravity and magnetics) and hyperspectral remote sensing datasets. These datasets were judged to be critical to assessment activities supported by the United States Agency for International Development (USAID). These assessments include coal, water, minerals, and earthquake hazards, as well as southern Afghanistan oil and gas basins in Katawaz and Helmand provinces. The geophysical and remote sensing data will be used to characterize the surface and subsurface rock composition, properties, and structure. They are baseline data needed for resource and hazard assessments and will support and expedite the decision making processes necessary for revitalization of the economic sector of Afghanistan. The airborne geophysical survey was conducted in the summer of 2006. Basic processing of the gravity and magnetic data has been completed (Ashan and others 2007; 2008).

Imaging spectrometers, which provide hyperspectral remote sensing data, measure the reflectance of light from the Earth's surface (Clark and others, 2003). Reflectance spectra can be interpreted to identify specific chemical transitions and molecular bonds and, thus, provide compositional information about specific materials and minerals occurring at the surface where physical- and chemical-weathering processes are active. Using well-characterized laboratory spectral databases as reference "standards," the USGS has conducted numerous remote sensing studies to determine the mineral composition of rocks and soils and map the distribution of minerals and vegetation on the Earth's surface (for example, Clark and others, 2003; Kokaly and others, 2003).

¹ Raymond F. Kokaly, USGS, MS 973 Box 25046, Denver Fed Center, Denver CO 80225, USA. raymond@usgs.gov

Hyperspectral remote sensing data collected in Afghanistan will be analyzed to produce thematic maps showing the distribution of selected minerals and vegetation, which will help define areas potentially hosting mineral deposits and will have applications in hazard, hydrologic, and infrastructure assessments. The HyMap imaging spectrometer (Cocks and others, 1998) was flown in Afghanistan from August 22 to October 2, 2007. HyMap has 512 cross-track pixels and covers the wavelength range 0.43 to 2.48 microns in 128 channels. Table 1 shows the nominal spectral characteristics of the four detectors in this sensor.

Table 1. HyMap sensor characteristics

Detector	Wavelength Range (nm)	Number of Channels	Average Sampling Interval (nm)	Spectral Bandpass (nm) average (min to max)
VNIR ¹	430 – 891	32	15	16 (13 to 20)
NIR ²	881 – 1344	32	15	16 (14 to 17)
SWIR1 ³	1401 – 1810	32	13	14 (13 to 16)
SWIR2 ⁴	1948 – 2480	32	17	20 (19 to 22)

¹Visible and Near-InfraRed ²Near-InfraRed ³ShortWave InfraRed detector 1 ⁴ShortWave InfraRed detector 2

Flight Line Planning

Prior to data collection, start and stop coordinates (in latitude and longitude) for each flight line were planned using the software “Survey Planning for Airborne Imaging Spectrometers” (SPAIS, pronounced “space”), a set of custom USGS programs written for the ENVI/IDL software system (ITT, 2007). As shown in Figure 1, flight lines were planned in north-south orientation. Characteristics of the HyMap sensor and the WB-57 aircraft, along with aircraft basing and political-boundary considerations, placed constraints on the design of the flight lines and the conduct of the airborne survey (table 2). With respect to the HyMap sensor, the principal constraints on flight line configuration came from the field of view of the sensor, which controls the width of the data swath, and the hold times of the liquid nitrogen dewars, which limit the hours of operation per flight. Aircraft characteristics also placed constraints on flight line planning, principally from the operational altitude, nominal ground speed, and maximum flight duration.

Additional constraints were placed on the planning of lines as follows. First, the inertial measurement unit, part of the HyMap system, can drift over time for straight and level flight lines, which restricts the flight line durations to a maximum of approximately 20 minutes. Near political borders, buffer zones were established to allow ample room for the WB-57 aircraft to make turns. A buffer zone of 46.3 km (25 nmi) was used for all borders except the border with Iran, for which a 64.8 km (35 nmi) buffer was used. The buffered area to be covered by HyMap flight lines, shown by the thin yellow outline in Figure 1, was 438,766 km².

Flight lines were laid out beginning in the west and moving to the east. The area covered by the sensor as it flies along the nadir track of the flight line is called the swath. The width of the swath varies as a function of surface elevation. The swath is narrower at higher elevations and the distances to the edges of the swath on either side of the nadir track are affected by differences in topography on either side. For the hyperspectral survey in Afghanistan, adjacent lines were planned with a minimum overlap of 40 percent of the “half-swath width” in order to account for these effects. Starting from the first flight line on the western side of the country, the overlap distance used by the SPAIS program to place each subsequent flight line came from the highest elevation at the eastern edge of the swath, which is the narrowest part of the eastern half of the

swath. For the 512 pixel swath of HyMap, this resulted in approximately 102 pixels of overlap at the highest elevation portions between adjacent flight lines. Determining the spacing in this manner allowed the lines to be spaced closer over high elevation areas of the country where the swaths are narrow and “spaced” wider at low elevations where the swaths are wider. In addition, using the percentage of the half-swath width that lies to the east guaranteed a minimum number of overlapping pixels, while keeping the spacing independent of the elevation effects on the width of the western half of the swath.

Table 2. Constraints used for flight line planning

Source of Constraint	Constraint Parameter	Constraint Value	Impact of Constraint
HyMap Sensor	Field of View	61.4°	Determines the swath width of 16.3 km using average country elevation (1,458 m) and nominal operating altitude
	Dewar Hold Time (from takeoff)	5 hours	Limits the number of flight lines that can be flown per sortie
	IFOV ¹	2.5 mrad along track	Defines the pixel size in along track direction, which can limit the ground speed, for a given scan rate, in order to avoid undersampling in the along track direction
	Scan Rate	8 Hz	Determines the nominal along track pixel spacing of 22.5 m using the nominal ground speed
HyMap GPS/inertial measurement unit	Max. Line Duration	~ 20 minutes	Limits lines to ~ 220 km length using the nominal ground speed
WB-57 Aircraft	Nominal Operating Altitude	15.24 km (50,000 ft)	Determines the swath width of 16.3 km using average country elevation of 1,458 m and sensor field of view
	Nominal Ground Speed	648.2 km/h (350 kts)	Determines the nominal along track spacing of 22.5 m using the given scan rate
	Max. Flight Duration	5.6 hours	If less than the dewar hold time plus the ferry-out time, it limits the number of flight lines that can be collected
Flight line overlap	Overlap	Minimum 40 percent	Applied to the narrowest part of the swath to the east of the flight line. Determines the flight line spacing.
Airfield Location	Latitude/Longitude	31.50° N, 65.83° E, Kandahar Airfield, Afghanistan	Coordinates of the airfield affect the number of lines that can be collected in each sortie, for example if located far from the collection area, the data collection time is reduced by the time it takes to ferry-in to the starting point of the data collection
Political Considerations	Border Buffer	64.8 km (35 nmi) for Iranian border, 46.3 km (25 nmi) elsewhere	Reduces the area covered and restricts flight lines to adhere to the buffer zone

¹Instantaneous Field Of View

The combination of sensor scan rate and aircraft ground speed defines the along track spacing. For the hyperspectral survey of Afghanistan, HyMap was set to a scan rate of 8 Hz and the WB-57 had an estimated ground speed of 648.2 km/h (350 kts). The combination of these values results in a 22.5 m along track pixel spacing at the average elevation of 1,458 m (4,783 ft) in Afghanistan. To avoid undersampling in the along-track direction the pixel size needs to exceed this value. For the HyMap/WB-57 combination, at the nominal operating altitude, the along-track pixel size is 34.5 m for this same average elevation. At the lowest elevation of 279 m (915 ft), the along-track pixel size is 37.4 m. At the highest elevation of 5,642 m (18,150 ft), the along-track pixel size is 24.0 m. Thus, according to our survey plan, undersampling in the along-track direction would be avoided and most of Afghanistan would be covered with significant scan line overlap.

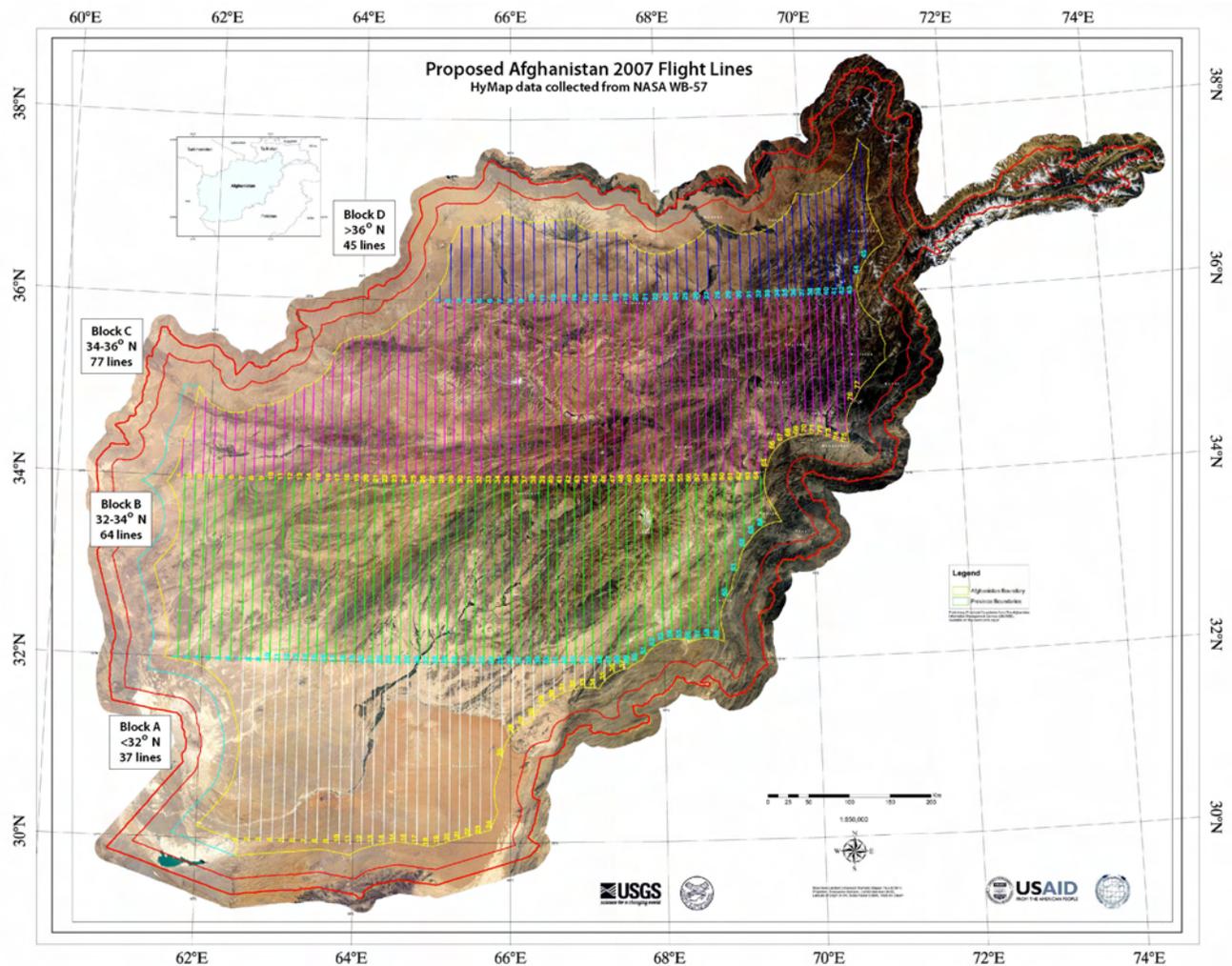


Figure 1. Planned USGS Afghanistan 2007 flight lines. Projection is Transverse Mercator, datum WGS-84. Thick red line is the Afghanistan border. Yellow line is the border zone buffer line (25 nmi on all borders except for the Iranian border where the buffer is 35 nmi).

Based in part on the above constraints, the country was divided into four “blocks” as defined by latitude (fig. 1). The southern-most block (A) covered the portion of the country below 32 degrees north (N) latitude. Block (B) covered 32 to 34 degrees N latitude. Block C covered 34 to 36 degrees N latitude. The northern-most block D covered the portion of the country above 36

degrees N latitude. For each block, the SPAIS program was run using an 85 meter digital elevation model (DEM), the buffer zone constraints, the HyMap sensor characteristics, and the WB-57 aircraft characteristics. To allow for overlap across blocks, an extra 3 km was added to the ends of each flight line, resulting in maximum lengths of 228 km (21 minutes flight time) for lines that would span a full 2 degrees of latitude. In Figure 1, the resulting 223 flight lines are depicted on a background Landsat image mosaic. These are the “standard data lines” for full country coverage of Afghanistan within our boundary buffer. The average planned flight line spacing was 11.5 km (minimum = 9.2 km, maximum = 13.8 km). The average swath width of the planned flight lines was 15.8 km (minimum = 11.7 km, maximum = 17.7 km). Additional flight lines, not depicted in Figure 1, were planned to pass over locations where field samples were collected and where measurements of field reflectance calibration sites were planned. These lines were designated “cross-calibration lines”.

Output of the SPAIS flight line planning software includes an estimate of the number of flights needed to acquire these flight lines based on the coordinates of the airfield, the start/stop coordinates and lengths of the flight lines, the turn times (estimated at 7 minutes for the WB-57), and the duration of each flight day (constrained by dewar hold time and maximum aircraft-operating duration). For the 223 flight lines, the total number of flights (sorties) was estimated to be approximately 19. Factoring in 50 percent down time due to aircraft maintenance, sensor maintenance, and weather, the collection time to complete the airborne hyperspectral survey was estimated to be 29 days.

HyMap Data Collection in 2007

Over the course of 43 days and 28 flights, from August 22 to October 2, 2007, a total of 218 flight lines of HyMap data were collected from the WB-57 aircraft. These flight lines include 207 standard data lines and 11 cross-calibration lines (see Figure 2), totaling 39,546 km in line length. The total area of Afghanistan imaged was approximately 438,012 km².

The majority of flight lines were collected according to the plan in Figure 1, with the exception of block A and the western-most lines in blocks B-D. For the last six flights of the data collection, the remaining lines were re-planned with less overlap. The observed stability of the WB-57 aircraft, with respect to roll, pitch and yaw, facilitated our reduction in overlap. Original flight lines D004-026 were re-planned with 16 percent overlap, resulting in 3 fewer lines to cover with the re-programmed lines D004-023. Flight line D001 was not flown. Similarly, C001-023 and B001-007 were re-planned with 14 percent overlap, reducing the number of flight lines needed to cover blocks C and B by 4 and 2, respectively. Originally planned lines A001 to 025 of block A were re-planned to lines A001-021 with 12 percent overlap. The eastern part of block A, originally covered by north-south lines A026-037, was re-planned to flight lines A022-028 and oriented 49.3 degrees east of north. Three lines, A029-031, were added to cover the Chagai hills in southern Afghanistan. Very poor visibility caused by dust storms on the last sortie of the deployment resulted in lines A002-006 and A015-019 being shortened so that they do not extend to 30 degrees N latitude as planned. Eleven cross-calibration lines were flown. Part of cross-calibration line K001 fills the gap between standard data lines A023 and A024.

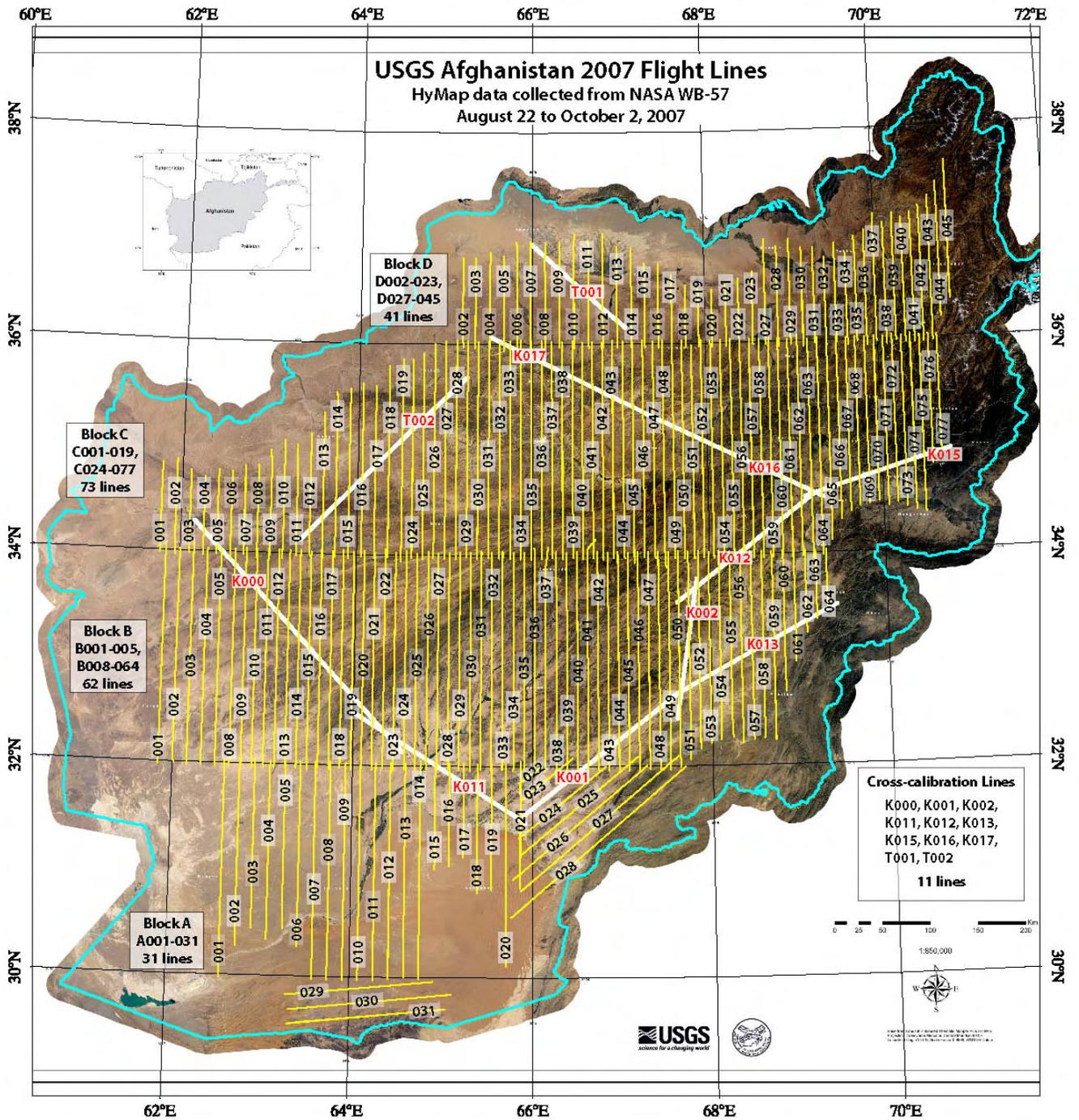


Figure 2. Actually flown USGS Afghanistan 2007 flight lines. Projection is Transverse Mercator, datum WGS-84. Cyan line is the Afghanistan border.

Compared to the flight line plan, the factors that were found to increase the number of sorties and days needed to actually complete the survey included:

- 1) five down days due to sensor problems caused by operating at high altitude
- 2) eight down days waiting for aircraft parts due in part to the difficulty of getting deliveries to the airfield
- 3) vacuum loss in HyMap's SWIR1 and SWIR2 dewars caused short collection times on two flights and led to two down days
- 4) less than optimal collection for the first seven flights, due to sensor problems
- 5) shorter than expected data collection times, measured from takeoff, that averaged 4.4 hours

On two occasions, right after detector dewars were vacuum pumped and when flight lines were located close to the Kandahar air field, data collection time reached the estimate of five hours used in the survey planning. During flights in Afghanistan, the actual altitudes and ground speeds were higher than originally planned. The mean altitude was 16.06 km (52,690 ft), minimum = 15.79 km (51,804 ft), maximum = 16.34 km (53,609 ft). The mean ground speed was 734.3 km/h (396.5 kts), minimum = 656.7 km/h (354.6 kts), maximum = 837.0 km/h (451.9 kts).

The increase in average ground speed was 13.8 percent above the planned value; however, the average altitude increased only 5.4 percent over the planned value. As a result the along-track pixel spacing (which scales with ground speed) increased more than the along-track pixel size (which scales with altitude). The consequence of the higher increase in ground speed was some undersampling in the along-track direction. Based on a preliminary analysis of the ground speeds, altitudes, and surface elevations, undersampling is a possibility in the data collected over higher elevations in the country, above 3,500 meters (11,483 ft), which is approximately 5 percent of the area covered by HyMap. Above this elevation limit, the along-track pixel spacing is likely to exceed the along track pixel size by one to two meters. The worst undersampling appears to be for the eastern-most lines in blocks C and D, caused by the very high terrain combined with strong tail winds from the north that increased ground speed for south-bound flight lines. The lines with high ground speeds include: C064, C066, C068, and C070, covered on sortie 8; C072, C074, and C076, covered on sortie 13; and D042 and D044 covered on sortie 14. The interspersed odd-numbered lines had lower ground speeds and did not suffer from undersampling. Considering the shorter than expected data-collection times, the ability to collect more data lines on each flight with higher ground speeds was judged to outweigh the disadvantage of potential along-track undersampling at high elevations.

The actual start and stop coordinates of all flown lines are given in Table 3, along with flight date, and time of collection.

Table 3. Coordinates and characteristics of HyMap lines flown in 2007

Flight Line Name	Sortie #	Flight Date	UTC ¹				
			Time of Collection hh:mm:ss	Start Latitude	Start Longitude	Stop Latitude	Stop Longitude
A001	28	10/2/2007	08:05:22	29.972124	62.580273	32.029545	62.579906
A002	28	10/2/2007	08:27:05	32.027592	62.747765	30.275385	62.749393
A003	28	10/2/2007	08:48:19	30.443548	62.918621	32.032040	62.918777
A004	28	10/2/2007	09:07:44	32.027386	63.088913	30.345081	63.088116
A005	28	10/2/2007	09:26:46	30.447092	63.261185	32.029652	63.257076

A006	28	10/2/2007	09:46:32	32.028580	63.424465	30.280624	63.424503
A007	26	9/30/2007	08:10:50	32.027447	63.592514	29.974766	63.591255
A008	26	9/30/2007	08:34:21	29.971659	63.754513	32.028042	63.757092
A009	26	9/30/2007	08:58:57	32.027325	63.923180	29.971437	63.922886
A010	26	9/30/2007	09:23:23	29.974432	64.087555	32.029762	64.088921
A011	26	9/30/2007	09:47:59	32.028687	64.256180	29.972521	64.254662
A012	26	9/30/2007	10:12:25	29.988613	64.419830	32.029861	64.420807
A013	26	9/30/2007	10:37:06	32.026783	64.587189	30.001612	64.586815
A014	26	9/30/2007	11:00:56	29.988289	64.750656	32.055565	64.751846
A015	28	10/2/2007	10:21:54	31.027197	64.916740	32.031624	64.916771
A016	28	10/2/2007	10:35:15	32.027229	65.077225	31.061424	65.074799
A017	28	10/2/2007	10:49:11	31.141773	65.233597	32.027760	65.233429
A018	28	10/2/2007	11:04:55	32.024864	65.384918	30.803396	65.384506
A019	28	10/2/2007	11:21:07	30.832409	65.542862	32.033409	65.540848
A020	27	10/1/2007	10:56:41	30.108656	65.708885	32.027615	65.701218
A021	27	10/1/2007	10:32:55	32.045490	65.863678	30.851093	65.860115
A022	27	10/1/2007	10:21:23	31.842796	65.848572	32.001701	66.098869
A023	27	10/1/2007	10:14:24	32.078110	66.441238	31.678572	65.868835
A024	27	10/1/2007	10:02:07	31.320242	65.841537	32.000179	66.807167
A025	27	10/1/2007	09:47:52	32.093502	67.168991	31.165438	65.868401
A026	27	10/1/2007	09:31:01	30.930769	65.778038	32.005318	67.266472
A027	27	10/1/2007	09:10:48	32.097301	67.622650	30.823099	65.867844
A028	27	10/1/2007	08:48:42	30.573492	65.763512	31.995325	67.694946
A029	27	10/1/2007	08:25:43	29.824646	63.309620	29.962446	64.906059
A030	27	10/1/2007	08:08:06	29.842499	65.107857	29.684048	63.346123
A031	27	10/1/2007	07:51:35	29.548759	63.333328	29.703384	65.040039
B001	24	9/28/2007	09:38:07	34.073719	61.846031	31.978779	61.841583
B002	24	9/28/2007	10:01:03	31.990074	62.011196	34.020382	62.000778
B003	26	9/30/2007	06:52:34	34.020714	62.157555	31.970463	62.157871
B004	26	9/30/2007	07:16:28	31.971947	62.312950	34.031094	62.314983
B005	26	9/30/2007	07:40:06	34.028496	62.471642	31.964602	62.470657
B008	19	9/21/2007	11:55:23	31.965862	62.629883	34.032043	62.629990
B009	19	9/21/2007	11:31:41	34.035809	62.756809	31.965347	62.756985
B010	19	9/21/2007	11:08:16	31.960194	62.879032	34.032303	62.878994
B011	19	9/21/2007	10:44:43	34.037342	63.004124	31.965561	63.003975
B012	19	9/21/2007	10:20:44	31.967615	63.126049	34.033459	63.127052

B013	19	9/21/2007	09:56:45	34.031593	63.249424	31.965904	63.248993
B014	19	9/21/2007	09:33:03	31.963531	63.369492	34.032837	63.370010
B015	18	9/17/2007	09:10:44	31.953680	63.493484	34.022552	63.489296
B016	18	9/17/2007	08:47:13	34.049267	63.610653	31.977661	63.609764
B017	18	9/17/2007	08:22:55	31.961380	63.735371	34.024570	63.732059
B018	18	9/17/2007	07:59:29	34.036983	63.853638	31.979948	63.854923
B019	18	9/17/2007	07:35:22	31.960926	63.977417	34.022816	63.975140
B020	18	9/17/2007	07:11:57	34.037266	64.092964	31.978275	64.092911
B021	18	9/17/2007	06:47:40	31.962265	64.211426	34.021843	64.209358
B022	18	9/17/2007	06:23:50	34.054237	64.329170	31.980976	64.328621
B023	18	9/17/2007	05:59:26	31.961405	64.446785	34.021812	64.447472
B024	18	9/17/2007	05:31:54	34.042450	64.568504	31.968777	64.567413
B025	17	9/16/2007	10:28:45	34.018566	64.688416	31.967522	64.688866
B026	17	9/16/2007	10:04:05	31.977324	64.816795	34.032730	64.816017
B027	17	9/16/2007	09:40:27	34.023693	64.930069	31.968115	64.931831
B028	17	9/16/2007	09:15:44	31.973734	65.055099	34.030422	65.052902
B029	17	9/16/2007	08:51:48	34.031853	65.173698	31.969517	65.175034
B030	17	9/16/2007	08:27:26	31.974377	65.298241	34.033195	65.298012
B031	17	9/16/2007	08:03:11	34.045078	65.416481	31.970285	65.416939
B032	17	9/16/2007	07:38:11	31.957541	65.535500	34.030056	65.535950
B033	17	9/16/2007	07:13:44	34.045948	65.656242	31.972569	65.652023
B034	16	9/15/2007	06:06:59	31.962019	65.781265	34.032764	65.781075
B035	16	9/15/2007	05:43:05	34.036228	65.902313	31.968710	65.898941
B036	15	9/14/2007	10:41:27	34.073910	66.014679	31.955479	66.017014
B037	15	9/14/2007	10:18:37	31.957645	66.137566	34.085136	66.167717
B038	15	9/14/2007	09:54:26	34.039577	66.262962	31.974222	66.263031
B039	15	9/14/2007	09:29:41	31.960991	66.381187	34.029041	66.380928
B040	15	9/14/2007	09:05:37	34.043987	66.498199	31.968033	66.499031
B041	15	9/14/2007	08:41:51	31.954849	66.615425	34.159031	66.710320
B042	15	9/14/2007	08:16:52	34.040115	66.730057	31.970829	66.730003
B043	15	9/14/2007	07:52:15	31.960949	66.845978	34.026474	66.846092
B044	15	9/14/2007	07:27:47	34.041088	66.959785	31.977633	66.959961
B045	15	9/14/2007	07:03:23	31.958145	67.070793	34.027279	67.070961
B046	15	9/14/2007	06:39:34	34.037300	67.187912	31.969109	67.184982
B047	12	9/10/2007	08:07:27	34.034359	67.302505	31.978226	67.301079
B048	7	9/5/2007	08:20:32	31.960108	67.417580	34.034946	67.416992

B049	7	9/5/2007	07:55:18	34.034374	67.531105	31.967699	67.530991
B050	7	9/5/2007	07:30:16	31.990335	67.639862	34.035908	67.639977
B051	7	9/5/2007	07:06:18	34.034409	67.749138	32.062412	67.756004
B052	6	9/4/2007	07:29:32	34.035351	67.868286	32.163132	67.867577
B053	6	9/4/2007	07:06:48	32.216206	67.987816	34.028709	67.986679
B054	6	9/4/2007	06:44:26	34.036575	68.102226	32.246082	68.101273
B055	6	9/4/2007	06:22:14	32.267876	68.235542	34.025433	68.223923
B056	5	9/3/2007	06:17:26	32.215542	68.341255	34.032124	68.341064
B057	4	8/30/2007	09:49:16	34.026146	68.458267	32.240601	68.462700
B058	4	8/30/2007	09:27:08	32.254524	68.579338	34.027958	68.584518
B059	4	8/30/2007	09:06:26	34.017170	68.698341	32.235401	68.706764
B060	4	8/30/2007	08:46:29	32.697247	68.833275	34.029049	68.828186
B061	4	8/30/2007	08:29:59	34.027481	68.954880	32.969460	68.953506
B062	4	8/30/2007	08:02:20	33.243706	69.085678	34.026875	69.079842
B063	4	8/30/2007	07:51:07	34.024643	69.197723	33.371891	69.199028
B064	4	8/30/2007	07:39:12	33.453495	69.319954	34.030514	69.320465
C001	24	9/28/2007	09:18:45	34.825958	61.773487	33.979733	61.770069
C002	24	9/28/2007	09:08:32	33.961853	61.940205	34.862396	61.936771
C003	24	9/28/2007	08:58:20	34.763992	62.100616	33.980316	62.099567
C004	24	9/28/2007	08:48:28	33.961834	62.258984	34.704079	62.259174
C005	24	9/28/2007	08:38:05	34.771595	62.416279	33.978722	62.413094
C006	24	9/28/2007	08:27:32	33.937008	62.568279	34.759651	62.567554
C007	22	9/24/2007	10:14:44	34.819820	62.715614	33.981037	62.720055
C008	22	9/24/2007	10:02:39	33.948025	62.868305	34.831459	62.867981
C009	22	9/24/2007	09:50:33	34.969303	62.999454	33.978828	63.015675
C010	22	9/24/2007	09:37:37	33.948086	63.153526	35.068981	63.161205
C011	22	9/24/2007	09:24:48	35.031334	63.300545	33.978291	63.312309
C012	22	9/24/2007	09:11:09	33.974232	63.472168	35.137058	63.460289
C013	22	9/24/2007	08:38:11	33.963287	63.607651	35.341824	63.606987
C014	22	9/24/2007	08:55:34	35.533375	63.743862	33.981762	63.752327
C015	22	9/24/2007	08:02:20	33.962555	63.902443	35.569485	63.900078
C016	22	9/24/2007	07:43:46	35.624142	64.046875	33.981892	64.047768
C017	22	9/24/2007	07:25:05	33.961246	64.197830	35.596928	64.195198
C018	22	9/24/2007	07:05:26	35.792370	64.342758	33.981247	64.348419
C019	22	9/24/2007	06:45:33	33.936134	64.502312	35.856976	64.502899
C024	11	9/9/2007	08:31:57	33.963821	64.621735	35.852337	64.618965

C025	11	9/9/2007	08:09:56	35.915565	64.740303	33.960503	64.744003
C026	11	9/9/2007	07:46:15	33.966904	64.870499	36.003956	64.870003
C027	11	9/9/2007	07:22:02	36.031673	64.993401	33.962040	64.996010
C028	11	9/9/2007	06:57:58	33.962017	65.123116	36.037430	65.120995
C029	21	9/23/2007	09:09:54	33.988693	65.244972	36.035343	65.245033
C030	21	9/23/2007	08:46:55	36.025578	65.366844	33.968071	65.366951
C031	21	9/23/2007	08:23:37	33.973499	65.491280	36.032852	65.491013
C032	21	9/23/2007	08:00:44	36.028469	65.614143	33.968647	65.615028
C033	11	9/9/2007	06:32:24	36.037807	65.737656	33.962440	65.737930
C034	11	9/9/2007	06:08:25	33.961876	65.859673	36.040932	65.858994
C035	11	9/9/2007	05:44:13	36.036213	65.980080	33.960228	65.980026
C036	11	9/9/2007	05:19:56	33.963936	66.099617	36.037277	66.099060
C037	12	9/10/2007	07:40:08	36.026432	66.219009	33.977783	66.217773
C038	12	9/10/2007	07:15:42	33.968300	66.338608	36.020088	66.336929
C039	12	9/10/2007	06:51:24	36.033009	66.456566	33.979973	66.455017
C040	12	9/10/2007	06:27:01	33.966454	66.569389	36.021202	66.567993
C041	12	9/10/2007	06:02:55	36.024879	66.686974	33.970566	66.685280
C042	12	9/10/2007	05:38:43	33.959511	66.800491	36.021374	66.799995
C043	12	9/10/2007	05:14:07	36.035259	66.916679	33.977913	66.916389
C044	12	9/10/2007	04:50:02	33.967941	67.040733	36.020798	67.036209
C045	24	9/28/2007	06:51:33	33.922138	67.149673	36.021034	67.149040
C046	10	9/8/2007	08:58:07	36.034557	67.268158	33.982590	67.268028
C047	10	9/8/2007	08:32:14	33.971928	67.388229	36.024956	67.385963
C048	10	9/8/2007	08:07:03	36.032448	67.497475	33.878624	67.516869
C049	10	9/8/2007	07:39:58	33.966606	67.614281	36.022640	67.611954
C050	10	9/8/2007	07:14:20	36.032021	67.721291	33.975346	67.721916
C051	10	9/8/2007	06:47:19	33.968616	67.835541	35.983593	67.832886
C052	10	9/8/2007	06:22:02	36.031750	67.944481	33.975319	67.943626
C053	10	9/8/2007	05:57:01	33.966537	68.054497	36.024258	68.054222
C054	9	9/7/2007	08:27:49	36.032814	68.167717	33.963730	68.169891
C055	9	9/7/2007	08:03:02	33.964771	68.286201	36.038200	68.283905
C056	9	9/7/2007	07:38:41	36.041737	68.393433	33.959732	68.395004
C057	9	9/7/2007	07:13:49	33.967461	68.505005	36.038670	68.504883
C058	9	9/7/2007	06:49:32	36.027294	68.618454	33.964317	68.618935
C059	9	9/7/2007	06:24:20	33.969894	68.728615	36.037731	68.728973
C060	21	9/23/2007	06:19:51	33.974651	68.835670	36.032604	68.835999

C061	21	9/23/2007	06:43:49	36.024311	68.948006	33.968010	68.948051
C062	20	9/22/2007	10:35:04	36.060242	69.059799	33.972347	69.061066
C063	20	9/22/2007	06:56:50	33.948513	69.179649	36.018684	69.180855
C064	8	9/6/2007	09:12:15	36.034111	69.292427	33.976345	69.290909
C065	8	9/6/2007	08:49:15	34.116577	69.396584	36.034142	69.403320
C066	8	9/6/2007	08:26:58	36.034088	69.517479	34.312187	69.515747
C067	8	9/6/2007	08:05:52	34.384205	69.627655	36.022923	69.625130
C068	8	9/6/2007	07:45:40	36.029507	69.734406	34.436829	69.731773
C069	8	9/6/2007	07:25:41	34.452461	69.842880	36.022030	69.841980
C070	8	9/6/2007	07:05:00	36.025917	69.955307	34.473240	69.949760
C071	13	9/11/2007	06:59:49	34.425434	70.057816	36.025234	70.056938
C072	13	9/11/2007	06:40:27	36.039825	70.161751	34.453491	70.161896
C073	13	9/11/2007	06:20:31	34.410221	70.268425	36.025585	70.267952
C074	13	9/11/2007	06:00:24	36.042034	70.372665	34.381947	70.373947
C075	13	9/11/2007	05:39:38	34.354729	70.479584	36.026268	70.480026
C076	13	9/11/2007	05:18:26	36.031044	70.581924	34.803314	70.581932
C077	13	9/11/2007	05:01:05	34.896465	70.682137	36.021107	70.682961
D002	21	9/23/2007	09:30:36	35.977406	65.193054	36.815323	65.185059
D003	21	9/23/2007	09:42:51	36.820065	65.332977	35.968117	65.330963
D004	24	9/28/2007	07:22:23	36.967743	65.807266	35.977993	65.816483
D005	24	9/28/2007	07:34:31	35.946457	65.664787	36.835049	65.659393
D006	24	9/28/2007	07:46:16	36.867546	65.506889	35.974480	65.499924
D007	23	9/25/2007	09:47:15	35.972801	65.971336	36.967579	65.970078
D008	23	9/25/2007	09:34:07	36.960533	66.141663	35.969398	66.139458
D009	23	9/25/2007	09:20:37	35.974640	66.310165	36.973076	66.307739
D010	23	9/25/2007	09:07:16	37.043182	66.483215	35.968658	66.476555
D011	23	9/25/2007	08:54:18	35.969063	66.647987	36.986427	66.645226
D012	23	9/25/2007	08:40:37	37.048958	66.818008	35.968498	66.812653
D013	23	9/25/2007	08:27:39	35.973248	66.978271	36.923237	66.976875
D014	23	9/25/2007	08:14:58	36.909061	67.149742	35.968372	67.144745
D015	23	9/25/2007	08:02:44	35.973225	67.299774	36.764202	67.299339
D016	23	9/25/2007	07:51:35	36.750862	67.461784	35.966202	67.455009
D017	23	9/25/2007	07:40:32	35.973892	67.613243	36.651867	67.613396
D018	23	9/25/2007	07:30:42	36.550720	67.772514	35.965866	67.770714
D019	23	9/25/2007	07:21:28	35.970299	67.922676	36.515816	67.923050
D020	23	9/25/2007	07:12:27	36.506676	68.083397	35.968170	68.082367

D021	23	9/25/2007	07:02:54	35.967892	68.241600	36.546268	68.241829
D022	23	9/25/2007	06:52:53	36.604259	68.392700	35.969311	68.391945
D023	23	9/25/2007	06:41:56	35.981960	68.553070	36.670059	68.555145
D027	20	9/22/2007	10:13:54	36.970470	68.704750	35.977234	68.702103
D028	20	9/22/2007	10:02:06	35.958233	68.853256	36.903435	68.850182
D029	20	9/22/2007	09:49:32	36.969379	68.997147	35.975246	68.992973
D030	20	9/22/2007	09:37:53	35.952370	69.142433	36.880688	69.138664
D031	20	9/22/2007	09:25:53	36.880169	69.275665	35.981827	69.273872
D032	20	9/22/2007	09:14:44	35.956081	69.407875	36.785957	69.406990
D033	20	9/22/2007	09:02:44	36.919914	69.529114	35.978775	69.525833
D034	20	9/22/2007	08:49:27	35.952564	69.656891	36.817230	69.653267
D035	20	9/22/2007	08:36:44	36.974911	69.756500	35.983692	69.765945
D036	20	9/22/2007	08:23:46	35.943027	69.882103	37.035347	69.878685
D037	20	9/22/2007	08:08:58	37.178722	69.995522	35.979954	69.989891
D038	20	9/22/2007	07:53:30	35.948544	70.109009	37.093430	70.106003
D039	20	9/22/2007	07:37:29	37.179737	70.221771	35.982929	70.214981
D040	20	9/22/2007	07:21:13	35.963593	70.330765	37.127232	70.323830
D041	14	9/12/2007	06:28:00	35.962093	70.430099	37.181450	70.430077
D042	14	9/12/2007	06:11:23	37.245518	70.530106	35.965771	70.534668
D043	14	9/12/2007	05:54:08	35.969578	70.640472	37.330532	70.643089
D044	14	9/12/2007	05:36:43	37.458996	70.742424	36.191723	70.747002
D045	14	9/12/2007	05:19:54	36.358044	70.860443	37.661324	70.861107
K000	26	9/30/2007	06:20:50	32.133125	64.549873	34.286678	62.154282
K001	2	8/24/2007	08:05:59	32.677864	67.609924	31.501389	65.843285
K002	8	9/6/2007	05:42:54	32.449684	67.612701	33.768139	67.850327
K011	2	8/24/2007	08:28:54	31.467379	65.913788	32.497540	64.004822
K012	13	9/11/2007	04:12:00	33.546810	67.624992	34.561146	69.211227
K013	4	8/30/2007	07:23:20	32.647472	67.539955	33.504414	69.428040
K015	13	9/11/2007	04:41:48	34.533806	69.098289	34.950806	70.781662
K016	21	9/23/2007	07:11:56	34.526077	69.313324	35.338249	67.311401
K017	21	9/23/2007	07:38:06	35.256653	67.514626	36.068298	65.512756
T001	24	9/28/2007	07:08:23	36.158886	67.071342	36.943649	65.990005
T002	24	9/28/2007	08:03:57	35.689156	65.244049	34.133327	63.359787

¹Coordinated Universal Time, for Afghanistan local time add 4.5 hours

Digital Files

A high-resolution image of figure 2 and GIS vector files of the flight lines are available at <http://pubs.usgs.gov/of/2008/1235/downloads>.

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